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Source: Valve Handbook

1 Introduction to Valves

1.1 The Valve

1.1.1 Definition of a Valve

By definition, *valves* are mechanical devices specifically designed to direct, start, stop, mix, or regulate the flow, pressure, or temperature of a process fluid. Valves can be designed to handle either liquid or gas applications.

By nature of their design, function, and application, valves come in a wide variety of styles, sizes, and pressure classes. The smallest industrial valves can weigh as little as 1 lb (0.45 kg) and fit comfortably in the human hand, while the largest can weigh up to 10 tons (9070 kg) and extend in height to over 24 ft (6.1 m). Industrial process valves can be used in pipeline sizes from 0.5 in [nominal diameter (DN) 15] to beyond 48 in (DN 1200), although over 90 percent of the valves used in process systems are installed in piping that is 4 in (DN 100) and smaller in size. Valves can be used in pressures from vacuum to over 13,000 psi (897 bar). An example of how process valves can vary in size is shown in Fig. 1.1.

Today's spectrum of available valves extends from simple water faucets to control valves equipped with microprocessors, which provide single-loop control of the process. The most common types in use today are gate, plug, ball, butterfly, check, pressure-relief, and globe valves.

Valves can be manufactured from a number of materials, with most valves made from steel, iron, plastic, brass, bronze, or a number of special alloys.

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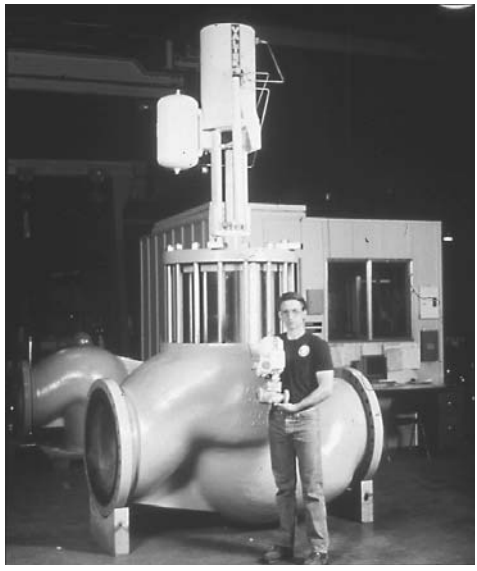

Figure 1.1 Size comparison between 30-in and 1-in globe valves. (*Courtesy of Valtek International*)

1.2 Valve Classification According to Function

1.2.1 Introduction to Function Classifications

By the nature of their design and function in handling process fluids, valves can be categorized into three areas: *on–off valves,* which handle the function of blocking the flow or allowing it to pass; *nonreturn valves,* which only allow flow to travel in one direction; and *throttling valves,* which allow for regulation of the flow at any point between fully open to fully closed.

One confusing aspect of defining valves by function is that specific valve-body designs—such as globe, gate, plug, ball, butterfly, and pinch styles—may fit into one, two, or all three classifications. For example, a plug valve may be used for on–off service, or with the addition of actuation, may be used as a throttling control valve. Another example is the globe-style body, which, depending on its internal design, may be an on–off, nonreturn, or throttling valve.

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Introduction to Valves

Therefore, the user should be careful when equating a particular valve-body style with a particular classification.

1.2.2 On–Off Valves

Sometimes referred to as *block valves,* on–off valves are used to start or stop the flow of the medium through the process. Common on–off valves include gate, plug, ball, pressure-relief, and tank-bottom valves (Fig. 1.2). A majority of on–off valves are hand-operated, although they can be automated with the addition of an actuator (Fig. 1.3).

On–off valves are commonly used in applications where the flow must be diverted around an area in which maintenance is being performed or where workers must be protected from potential safety hazards. They are also helpful in mixing applications where a number of fluids are combined for a predetermined amount of time and when exact measurements are not required. Safety management systems also require automated on–off valves to immediately shut off the system when an emergency situation occurs.

Pressure-relief valves are self-actuated on–off valves that open only when a preset pressure is surpassed (Fig. 1.4). Such valves are divided into two families: relief valves and safety valves. Relief valves are used to guard against overpressurization of a liquid service. On the other hand, safety valves are applied in gas applications where overpressurization of the system presents a safety or process hazard and must be vented.

Figure 1.2 Tank bottom valve used in a steel processing application. (*Courtesy of Kammer USA*)

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Figure 1.3 Quarter-turn plug valve with rack and pinion actuation system in chemical service. (*Courtesy of Automax, Inc. and The Duriron Company, Valve Division*)

Figure 1.4 Pressure-relief valve being tested for correct cracking pressure. (*Courtesy of Valtek Houston Service Center*)

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Introduction to Valves

1.2.3 Nonreturn Valves

Nonreturn valves allow the fluid to flow only in the desired direction. The design is such that any flow or pressure in the opposite direction is mechanically restricted from occurring. All check valves are nonreturn valves (Fig. 1.5).

Nonreturn valves are used to prevent backflow of fluid, which could damage equipment or upset the process. Such valves are especially useful in protecting a pump in liquid applications or a compressor in gas applications from backflow when the pump or compressor is shut down. Nonreturn valves are also applied in process systems that have varying pressures, which must be kept separate.

1.2.4 Throttling Valves

Throttling valves are used to regulate the flow, temperature, or pressure of the service. These valves can move to any position within the stroke of the valve and hold that position, including the full-open or full-closed positions. Therefore, they can act as on–off valves also. Although many throttling valve designs are provided with a hand-operated

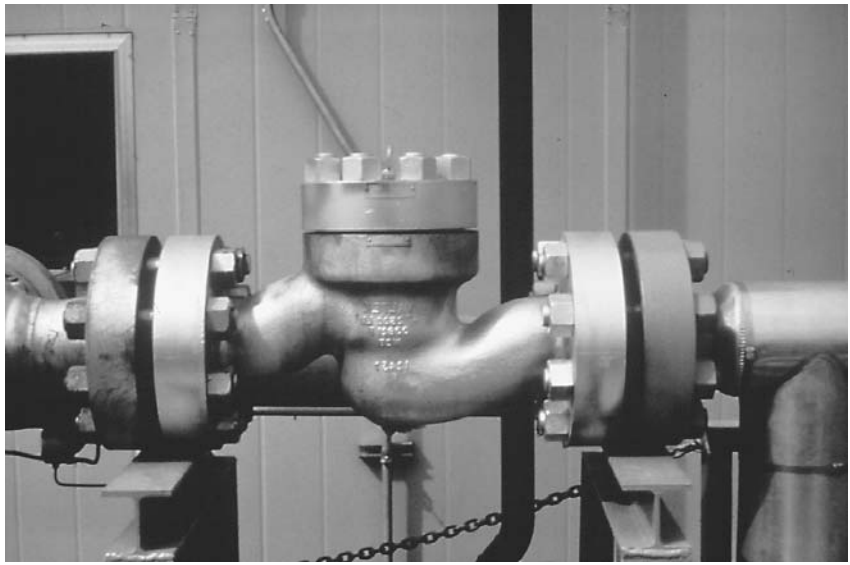

Figure 1.5 Piston check valve in natural gas service. (*Courtesy of Valtek International*)

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manual handwheel or lever, some are equipped with actuators or actuation systems, which provide greater thrust and positioning capability, as well as automatic control (Fig. 1.6).

Pressure regulators are throttling valves that vary the valve's position to maintain constant pressure downstream (Fig. 1.7). If the pressure builds downstream, the regulator closes slightly to decrease the pressure. If the pressure decreases downstream, the regulator opens to build pressure.

As part of the family of throttling valves, *automatic control valves,* sometimes referred to simply as *control valves,* is a term commonly used to describe valves that are capable of varying flow conditions to match the process requirements. To achieve automatic control, these valves are always equipped with actuators. Actuators are designed to receive a command signal and convert it into a specific valve position

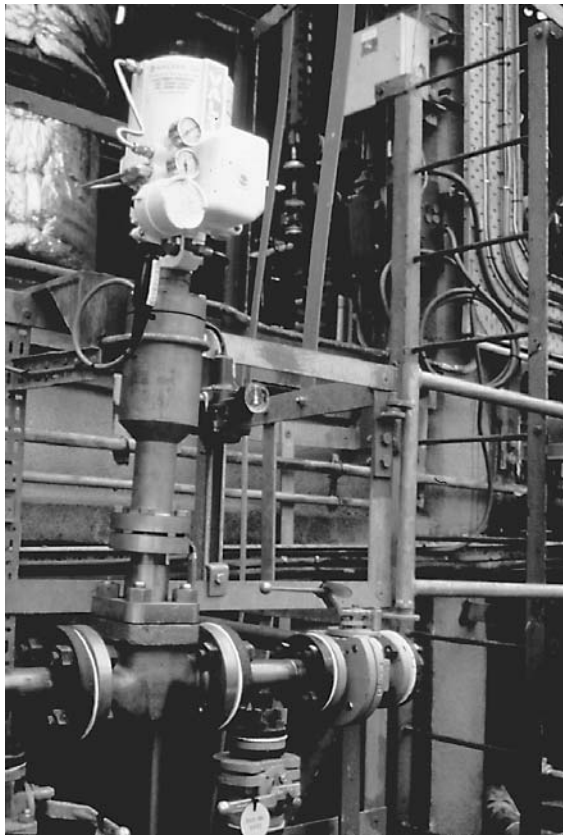

Figure 1.6 Globe control valve with extended bonnet (left) with quarter-turn blocking ball valves (right and bottom) in refining service. (*Courtesy of Valtek International*)

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Introduction to Valves

Figure 1.7 Pressure regulator. (*Courtesy of Valtek International*)

using an outside power source (air, electric, or hydraulic), which matches the performance needed for that specific moment.

1.2.5 Final Control Elements within a Control Loop

Control valves are the most commonly used final control element. The term *final control element* refers to the high-performance equipment needed to provide the power and accuracy to control the flowing medium to the desired service conditions. Other control elements include metering pumps, louvers, dampers, variable-pitch fan blades, and electric current-control devices.

As a final control element, the control valve is part of the *control loop,* which usually consists of two other elements besides the control valves: the *sensing element* and the *controller.* The sensing element (or sensor) measures a specific process condition, such as the fluid pressure, level, or temperature. The sensing element uses a transmitter to send a signal with information about the process condition to the controller or a much larger distributive control system. The controller receives the input from the sensor and compares it to the set point, or the desired value needed for that portion of the process. By comparing the actual input against the set point, the controller can make any needed corrections to the process by sending a signal to the final control element, which is most likely a control valve. The valve makes the change according to the signal from the controller, which is measured and verified by the sensing element, completing the loop. Figure 1.8 shows a

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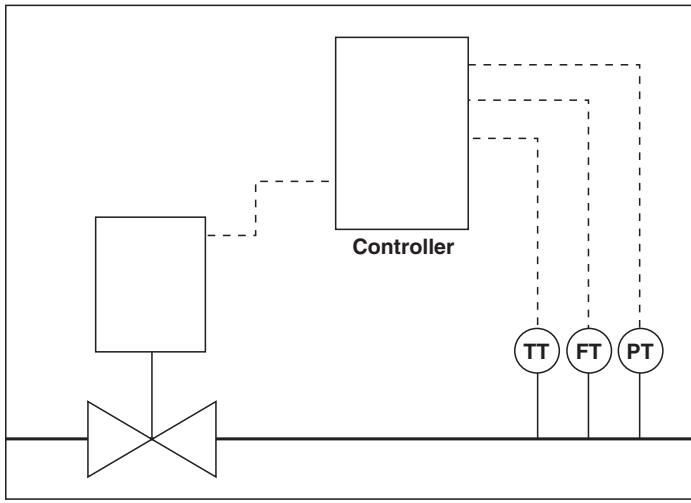

Figure 1.8 Control loop schematic showing the relationship among flow (FT), pressure (PT), and temperature (TT) transmitters, and the controller and control valve. (*Courtesy of Valtek International*)

diagram of a common control loop, which links a controller with the flow (FT), pressure (PT), and temperature transmitters (TT) and a control valve.

1.3 Classification According to Application

1.3.1 Introduction to Application Classifications

Although valves are often classified according to function, they are also grouped according to the application, which often dictates the features of the design. Three classifications are used: *general service valves,* which describes a versatile valve design that can be used in numerous applications without modification; *special service valves,* which are specially designed for a specific application; and *severe service valves,* which are highly engineered to avoid the side effects of difficult applications.

1.3.2 General Service Valves

General service valves are those valves that are designed for the majority of commonplace applications that have lower-pressure ratings between American National Standards Institute Class 150 and 600

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Introduction to Valves

(between PN 16 and PN 100), moderate-temperature ratings between −50 and 650°F (between −46 and 343°C), noncorrosive fluids, and common pressure drops that do not result in cavitation or flashing. General service valves have some degree of interchangeability and flexibility built into the design to allow them to be used in a wider range of applications. Their body materials are specified as carbon or stainless steels. Figure 1.9 shows an example of two general service valves, one manually operated and the other automated.

1.3.3 Special Service Valves

Special service valves is a term used for custom-engineered valves that are designed for a single application that is outside normal process applications. Because of its unique design and engineering, it will only function inside the parameters and service conditions relating to that particular application. Such valves usually handle a demanding temperature, high pressure, or a corrosive medium. Figure 1.10 shows a control valve designed with a sweep-style body and ceramic trim to handle an erosive mining application involving sand particulates and high-pressure air.

Figure 1.9 Wedge gate valves used in a blocking service to bypass general service control valves in a gasification process. (*Courtesy of Valtek International*)

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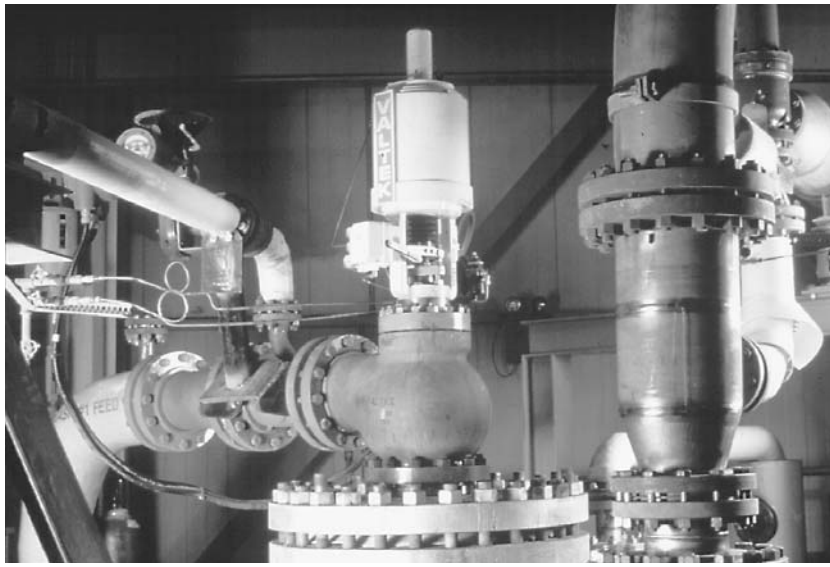

Figure 1.10 Sweep-style globe valve used in an erosive mining application involving high-pressure air and sand particulates. (*Courtesy of Valtek International*)

1.3.4 Severe Service Valves

Related to special service valves are *severe service valves,* which are valves equipped with special features to handle volatile applications, such as high pressure drops that result in severe cavitation, flashing, choking, or high noise levels (which is covered in greater detail in Chap. 9). Such valves may have highly engineered trims in globe-style valves, or special disks or balls in rotary valves to either minimize or prevent the effects of the application.

In addition, the service conditions or process application may require special actuation to overcome the forces of the process. Figure 1.11 shows a severe service valve engineered to handle 1100°F (593°C) liquid-sodium application with multistage trim to handle a high pressure drop and a bonnet with special cooling fins. The electrohydraulic actuator was capable of producing 200,000 lb (889,600 N) of thrust.

1.4 Classification According to Motion

1.4.1 Introduction to Motion Classifications

Some users classify valves according to the mechanical motion of the valve. *Linear-motion valves* (also commonly called *linear valves*)

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Introduction to Valves

have a sliding-stem design that pushes a closure element into an open or closed position. (The term *closure element* is used to describe any internal valve device that is used to open, close, or regulate the flow.) Gate, globe, pinch, diaphragm, split-body, three-way, and angle valves all fit into this classification. Linear valves are known for their simple design, easy maintenance, and versatility with more size, pressure class, and design options than other motion classifications—therefore, they are the most common type of valve in existence today.

On the other hand, *rotary-motion valves* (also called *rotary valves*) use a closure element that rotates—through a quarter-turn or 45° range—to open or block the flow. Rotary valves are usually smaller in size and weigh less than comparable linear valves, size for size. Application-wise, they are limited to certain pressure drops and are prone to cavitation and flashing problems. However, as rotary-valve designs have matured, they have overcome these inherent limitations and are now being used at an increasing rate.

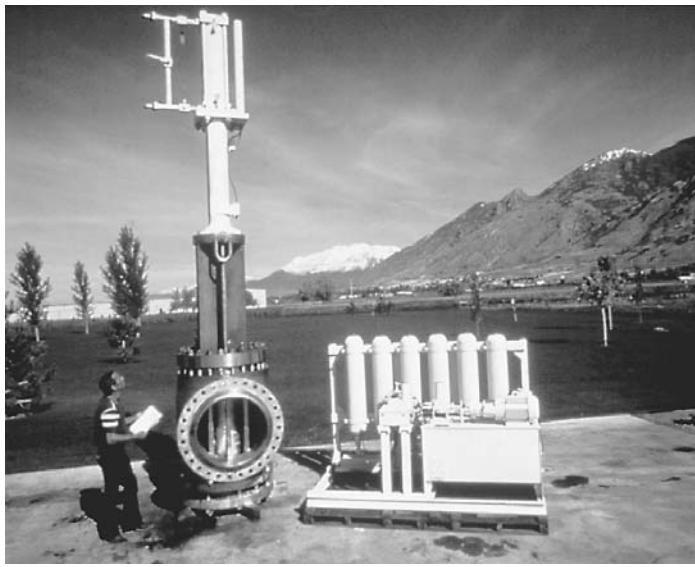

Figure 1.11 Severe service valve designed to handle high-pressure-drop, high-temperature liquid-sodium application. (*Courtesy of Valtek International*)

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1.5 Classification According to Port Size

1.5.1 Full-Port Valves

In process systems, most valves are designed to restrict the flow to some extent by allowing the flow passageway or area of the closure element to be smaller than the inside diameter of the pipeline. On the other hand, some gate and ball valves can be designed so that internal flow passageways are large enough to pass flow without a significant restriction. Such valves are called *full-port valves* because the internal flow is equal to the full area of the inlet port.

Full-port valves are used primarily with on–off and blocking services, where the flow must be stopped or diverted. Full-port valves also allow for the use of a *pig* in the pipeline. The pig is a self-driven (or flow-driven) mechanism designed to scour the inside of the pipeline and to remove any process buildup or scale.

1.5.2 Reduced-Port Valves

On the other hand, *reduced-port valves* are those valves whose closure elements restrict the flow. The flow area of that port of the closure element is less than the area of the inside diameter of the pipeline. For example, the seat in linear globe valves or a sleeve passageway in plug valves would have the same flow area as the inside of the inlet and outlet ports of the valve body. This restriction allows the valve to take a pressure drop as flow moves through the closure element, allowing a partial pressure recovery after the flow moves past the restriction.

The primary purpose of reduced-port valves is to control the flow through reduced flow or through throttling, which is defined as regulating the closure element to provide varying levels of flow at a certain opening of the valve.

1.6 Common Piping Nomenclature

1.6.1 Introduction to Piping Nomenclature

Although a complete glossary is included in this handbook, the reader should be acquainted with the piping nomenclature commonly used in

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Introduction to Valves

the global valve industry. Because the valve industry, along with a good portion of the process industry, has been driven by developments and companies originating in North America over the past 50 years, valve and piping nomenclature has been heavily influenced by the imperial system, which uses such terms as *pounds per square inch* (*psi*) to refer to pressure or *nominal pipe size* (*NPS*) to refer to valve and pipe size (in inches across the pipe's inside diameter). These terms are still in use today in the United States and are based upon the nomenclature established by the American National Standards Institute (ANSI).

Outside of the United States, valve and piping nomenclature is based on the International System of Units (metric system), which was established by the International Standards Organization (ISO). According to the metric system, the basic unit measurement is a *meter,* and distances are related in multiples of meters (kilometers, e.g.) or as equal units of a meter (centimeters, millimeters). Typically metric valve measurements are called out in millimeters and pressures are noted in *kilopascal* (kPa) (or *bar*). ISO standards refer to pipe diameter as *nominal diameter* (DN) and pressure ratings as *nominal pressure* (PN). Tables 1.1 and 1.2 provide quick reference for both ANSI and ISO standards.

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Table 1.1 Nominal Pipe Size vs. Nominal Diameter*

Nominal Pipe Size (NPS) *(inches)*	Nominal Diameter (DN) *(millimeters)*
0.25	6
0.5	15
0.75	20
1.0	25
1.25	32
1.5	40
2.0	50
2.5	65
3.0	80
4.0	100
6.0	150
8.0	200
10.0	250
12.0	300
14.0	350
16.0	400
18.0	450
20.0	500
24.0	600
36.0	900
42.0	1000
48.0	1200

**Data courtesy of Kammer Valve.*

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Table 1.2 ANSI Pressure Class vs. Nominal Pressure*

ANSI Pressure Class *pounds of force per square inch of surface area*	Nominal Pressure (PN) *allowable pressure in bar*
150	16
300	40
600	100
900	160
1500	250
2500	400
4500	700

Note: PN is an approximation to the corresponding ANSI pressure class, and should not be used as an exact correlation between the two standards. PN correlates to DIN (Deutsche Industrie Norme) pressure–temperature rating standards, which may vary significantly from ANSI pressure–temperature ratings.

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